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Drop punt kicking induces eccentric knee flexor weakness associated with reductions in hamstring electromyographic activity

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Abstract

Objectives: To examine the effect of 100 drop punt kicks on isokinetic knee flexor strength and surface electromyographic (sEMG) activity of bicep femoris (BF) and medial hamstrings (MH).

Design: Randomised control study. **Methods:** Thirty-six recreational footballers were randomly assigned to kicking or control groups. Dynamometry was conducted immediately before and after the kicking or 10 minutes of sitting (control). **Results:** Eccentric strength declined more in the kicking than the control group ($p < 0.001$; $d = 1.60$), with greater reductions in eccentric than concentric strength after kicking ($p = 0.001$; $d = 0.92$). No significant between group differences in concentric strength change were observed ($p = 0.089$; $d = 0.60$). The decline in normalized eccentric hamstring sEMG (BF and MH combined) was greater in the kicking than the control group ($p < 0.001$; $d = 1.78$), while changes in concentric hamstring sEMG did not differ between groups ($p = 0.863$; $d = 0.04$). Post-kicking reductions in sEMG were greater in eccentric than concentric actions for both BF ($p = 0.008$; $d = 0.77$) and MH ($p < 0.001$; $d = 1.11$). In contrast,

the control group exhibited smaller reductions in eccentric than concentric hamstring sEMG for BF ($p = 0.026$; $d = 0.64$) and MH ($p = 0.032$; $d = 0.53$). Reductions in BF sEMG were correlated with eccentric strength decline ($R = 0.645$; $p = 0.007$). Conclusions: Reductions in knee flexor strength and hamstring sEMG are largely limited to eccentric contractions and this should be considered when planning training loads in Australian Football.

Keywords

Australia; Football; Isokinetic dynamometry; Neuromuscular fatigue; Knee; Thigh

1. Introduction

Australian Rules football is a popular contact sport which demands that players possess ball handling skills and high aerobic and anaerobic fitness capacities.¹ Other than running with the ball, there are two methods by which players can move the ball around the field; the hand-ball and the drop punt kick. This kick is responsible for a small proportion of hamstring strain injuries^{2,3} which represents the most common cause of lost playing time in the game.⁴

Hamstring strain injuries commonly occur from two mechanisms, high-speed running⁵ and stretching at extreme joint positions, which are comparable to those adopted during the follow through of drop punt kicking.⁶ In both running and kicking the hamstrings essentially act as brakes to decelerate the flexing hip and extending knee. During this action these muscles experience high-force eccentric contractions coupled with moderate to high muscle strains,⁷ the combination of which is likely to cause injury.⁸ In contrast to high-speed running injuries, which most often affect the long head of biceps femoris,⁵ injuries consequent to kicking generally result in greater time-loss, and smaller strength deficits.⁹ Both injuries therefore create a substantial financial burden¹⁰ and have a negative impact upon team performance.

Neuromuscular fatigue is also thought to play a role in hamstring injury with studies of soccer showing that a majority of such incidents occur towards the end of each 45 minute 'half'.¹¹ This may be partly explained by significant reductions in eccentric knee flexor strength and biceps femoris muscle activation¹² that occur as a result of running-induced fatigue. However, it is unknown whether similar changes occur as a consequence of kicking, which has been reported to involve significantly greater activity of the semitendinosus than the biceps femoris or semimembranosus muscles.¹³

Given the vital role of the drop punt kick in Australian Football and its association with hamstring strain injury, it is important to further investigate the effect of kicking on hamstring strength and neuromuscular function. Therefore, the aim of this study was to determine if reductions in knee flexor strength and hamstring sEMG activity occurred following repetitive

high force kicking. We hypothesised that: 1) kicking would result in a contraction mode specific decline in eccentric knee flexor strength; and 2) this strength decline would be associated with a reduction in medial hamstring sEMG.

1 1. Methods

Thirty-six recreational level male footballers (age = 21.8 ± 3.1 years, stature = 183.9 ± 7.5 cm, mass = 78.7 ± 16.4 kg and football playing experience = 12.6 ± 4.7 years) were recruited for this randomised controlled study. None of the participants had a history of hamstring strain injury in the past 36 months. Each player was informed of the risks and benefits of the investigation prior to providing written consent to participate and was then randomly assigned into either a kicking group (K) (n=18) or control group that performed no kicking (NK) (n=18). The kicking protocol consisted of 100 drop punt kicks, as employed previously by others.¹³ Each participant completed a standardized 5 minute warm-up that consisted of lower body dynamic stretches and ten kicks of progressively increasing intensity. Participants were then instructed to kick an Australian Rules football (SHERRIN, Melbourne, Australia) as quickly and with as much force as possible into a nylon net.¹³ An assistant collected the balls and passed them to the kicker to ensure quick ball access and prevent unwanted muscle activity when retrieving balls from the floor. Those in the control group were seated for 10 min, which is the approximate time required to complete the kicking protocol. Ethical approval for this study was granted by the university's Human Research Ethics Committee.

Prior to and after completing the kicking or ten minutes of sitting, participant's knee flexor strength on their dominant (preferred kicking) limb was assessed via isokinetic dynamometry (Biodex® System 3, Shirley, USA). All had been familiarized with the dynamometer tests 7 – 9 days before formal testing. Participants were seated on the dynamometer with a hip angle of approximately 85° from full extension and were restrained by straps around the tested thigh, waist, and chest to minimise compensatory movements.¹² All seating variables (e.g., seat height, pad position) were recorded to ensure the replication of positions. Gravity correction for limb weight was also conducted and range of motion (ROM) was set between 5° and 90° of knee flexion. The warm-up prior to the initial strength test involved three sets of four concentric knee extension and flexion contractions at an angular velocity of 240°s^{-1} , with progressively increasing intensities of effort.¹² The test protocol began one minute following the final warm-up set and as soon as possible after completion of kicking (~2.5 minutes) and consisted of one set of three concentric and eccentric maximum voluntary contractions (MVCs) of the knee flexors at 180°s^{-1} with a between set rest period of 60 s. The testing speed was chosen based on previous studies that have investigated the effect of fatigue on knee flexor strength.¹² The investigators loudly exhorted participants to exert maximal effort during all contractions. The testing order of contraction modes was randomised and counter balanced across the participant pool.

We have previously examined the test-retest reliability of this isokinetic protocol. Intraclass correlations (ICCs) and typical error as a coefficient of variation (%TE) for peak knee flexor torque under both concentric 180°s^{-1} (ICC = 0.93; TE% = 4.5%) and eccentric 180°s^{-1} (ICC = 0.82; TE% = 6.0%) conditions were acquired.¹² These results are comparable to previously published data for concentric contractions (ICC = 0.97 and 0.96)¹⁴ and eccentric contractions (ICC = 0.83).¹⁵

Neonatal ECG electrodes (10 mm in diameter, 15 mm interelectrode distance) (Ambu®, Ballerup, Denmark) were used to record medial hamstring and biceps femoris surface electromyographic (sEMG) activity.¹² Following the initial skin preparation, electrodes were positioned on the posterior thigh half way between the ischial tuberosity and tibial epicondyles with electrodes oriented parallel to the line between these two land marks. The reference electrode was placed on the head of the ipsilateral fibula. Muscle bellies of the medial and lateral portions of the hamstrings were identified via palpation during forceful isometric knee flexion, and correct electrode placement confirmed by observing sEMG activity during active internal and external rotation of the flexed knee, respectively. Electrodes were then covered by rectangular sections (20cm x 15cm) using fixomull stretch tape (BSN medical, Luxembourg City, Luxembourg) to ensure adhesion during the kicking protocol. To minimise sEMG movement artifact that may arise from the dynamometer chair, participants sat on a custom-made foam pad with cut-outs under the sites of electrode placement.

Dynamometer torque and lever position data and sEMG signals were transferred to a computer at 1000Hz via a 16-bit PowerLab 26T AD recording unit (ADInstruments, Bella Vista, Australia) (amplification = 1000; common mode rejection ratio = 110 dB). sEMG data was filtered using a Bessel filter with a frequency bandwidth of 10–500 Hz and then smoothed and rectified over 100ms moving windows.¹² For each contraction mode, mean knee flexor torque and sEMG data were taken between the knee angles of 15° and 35° (full knee extension = 0°). Pilot work in this laboratory has shown that hamstring sEMG is most sensitive to the effects of fatiguing exercise at these angles. Surface EMG was averaged, for each contraction mode and at each time point, across the three contractions. Average eccentric sEMG from before kicking and average concentric and eccentric sEMG from post-kicking were normalized to the average sEMG signal obtained during the three concentric knee flexion efforts obtained in the pre-test.

Levene's tests for homogeneity were used to assess the equality of variances for each variable ($p > 0.05$). Shapiro-Wilks test were conducted to assess normality. Knee flexor strength changes were analysed via a contraction mode (eccentric & concentric) by group (K & NK) repeated measures ANOVA. Changes in normalised sEMG were analysed via a contraction mode (eccentric & concentric) by group (K & NK) by muscles (BF & MH) repeated measures ANOVA. When interactions were significant, post-hoc pairwise comparisons were made with Bonferroni corrections for multiple comparisons. Pearson's correlation was used to assess the strength of the relationship between torque and sEMG changes. Statistical significance was set at $P \leq 0.05$ and Cohen d effect sizes calculated using the following thresholds; trivial < 0.20 , small $= 0.20-0.49$, medium $= 0.50-0.79$ and large > 0.80 .¹⁶ All statistical analyses were carried out using SPSS (version 21; SPSS Inc., Chicago, USA).

2 1. Results

The observed power for strength change (contraction mode x group) was 0.95. The observed power for normalized sEMG (contraction mode x group) was 0.99.

A significant interaction was observed for contraction mode by group ($p = 0.001$). Furthermore, significant main effects were found for group ($p < 0.001$) and contraction mode ($p < 0.001$). Eccentric strength declined significantly more in the kicking ($-19 \pm 13\%$) than the control group ($-1 \pm 9\%$) (mean difference = -28 Nm, 95%CI = -41 to -15 ; $p < 0.001$; $d = 1.60$). In contrast, concentric strength changes in the kicking ($-7 \pm 13\%$) and control groups ($0 \pm 10\%$) were not significantly different (mean difference = -7 Nm, 95%CI = -15 to 1 ; $p = 0.089$; $d = 0.60$) (Figure 1).

Strength loss after kicking was significantly greater when measured eccentrically ($-19 \pm 13\%$) than concentrically ($-7 \pm 13\%$) (mean difference = -24 Nm, 95%CI = -32 to -16 ; $p < 0.001$; $d = 0.92$). By contrast, the small eccentric ($-1 \pm 9\%$) and concentric ($0 \pm 10\%$) strength changes exhibited by the control group were not significantly different (mean difference = -3 Nm, 95%CI = -11 to 5 ; $p = 0.471$; $d = 0.10$).

No significant contraction mode (Con v Ecc) by muscle (BF v MH) by group (K v NK) interaction was found for changes in sEMG ($p = 0.56$). However, there was a significant interaction for contraction mode by group ($p < 0.001$), along with a significant main effect for group ($p = 0.01$) and no significant main effect for contraction mode ($p = 0.283$).

Pairwise comparisons, subsequent to the contraction mode by group analysis, revealed that the decline in normalised eccentric sEMG (for biceps femoris and medial hamstring combined) was greater in the kicking (-0.35) than the control group (-0.01) (mean difference = -0.34 , 95%CI = -0.45 to -0.23 ; $p < 0.001$; $d = 1.78$). By contrast, changes in concentric hamstring sEMG in the kicking (-0.15) and control (-0.14) groups were not significantly different from each other (mean difference = -0.01 , 95%CI = -0.15 to 0.12 ; $p = 0.863$; $d = 0.04$).

Post kicking reductions in normalised sEMG were significantly greater in eccentric than concentric actions for both biceps femoris (mean difference = -0.16 , 95%CI = -0.28 to -0.05 ; $p = 0.008$, $d = 0.77$) and medial hamstrings (mean difference = -0.23 , 95%CI = -0.34 to -0.12 ; $p < 0.001$; $d = 1.11$). In contrast, the control group exhibited smaller reductions in eccentric than concentric normalised sEMG for the biceps femoris (mean difference = 0.14 , 95%CI = 0.02 to 0.25 ; $p = 0.026$; $d = 0.64$) and medial hamstrings (mean difference = 0.12 , 95%CI = 0.01 to 0.23 ; $p = 0.032$; $d = 0.53$) (Figure 2) No significant between-muscle differences (biceps femoris v medial hamstrings) were observed for sEMG changes in either contraction mode in either group ($p > 0.05$ for all).

The reductions in biceps femoris sEMG activity were correlated with the decline in eccentric torque ($R = 0.645$; $p = 0.007$) whereas changes in medial hamstring sEMG activity were not ($R = -0.003$; $p = 0.990$).

3 1. Discussion

As far as we are aware, this is the first study to have investigated the immediate effects of drop punt kicking on isokinetic concentric and eccentric knee flexor strength and associated electromyographic signals. The results show, as hypothesised and as reported previously for repeated sprint running,^{12, 17} that strength loss after kicking-induced fatigue is largely specific to the eccentric contraction mode. As hypothesised, the loss of eccentric knee flexor strength was accompanied by reductions in medial hamstring sEMG, although we also observed significant reductions in biceps femoris sEMG which were unanticipated.

Low levels of eccentric knee flexor strength, measured in unfatigued athletes in pre-season tests, may contribute to an elevated risk of subsequent hamstring strain injury^{2, 3} although there is some disagreement in the literature.^{18, 19} A recent extremely large (n = 614) study has also suggested that any association between isokinetic eccentric knee flexor strength and future hamstring injury is weak.²⁰ Nevertheless, an association between fatigue and hamstring injury has been assumed after reports that these insults are more likely to occur in the later portions of each playing period in soccer²¹ and Rugby.²² Furthermore, running induced fatigue^{12, 17} and now kicking, have been shown to result in preferential losses in eccentric strength and there is some basic research which suggests that fatigued skeletal muscle²³ fails (exhibits strain injury) at lower stresses than unfatigued muscle. It remains possible then, that the preferential loss of eccentric strength after kicking and running may contribute to hamstring injury in Australian Rules football and other sports with similar demands.

The current study shows that eccentric strength loss after kicking is associated with a contraction mode-specific decline in sEMG within both the lateral and medial hamstrings and we have previously reported that reductions in maximal eccentric sEMG after sprint running were limited to the biceps femoris.¹² While not conclusive proof, the current findings are consistent with the possibility that reduced neural drive contributes to strength loss after kicking. Incomplete activation of isolated mammalian skeletal muscle is known to reduce the stresses associated with tissue failure,²⁴ so this decline in muscle activation may play a role in hamstring strain injuries.

Most hamstring injuries in Australian Football,² soccer³ and Rugby¹⁸ occur during running and affect the long head of the biceps femoris. While there is a relative dearth of published information on the site of hamstring lesions after kicking injuries, the joint positions in the kick's follow-through (flexed hip and near fully extended knee) are similar to those observed in slow stretch maneuvers that are typically associated with injuries to the semimembranosus.⁶ It should be noted, however, that functional magnetic resonance imaging has revealed significantly greater involvement of the semitendinosus than either the biceps femoris or semimembranosus muscles after 100 drop punt kicks.¹³ This suggests that the semitendinosus is more likely than the other two-joint hamstrings to exhibit kicking-induced fatigue, although it is unclear whether this has any bearing on the site of hamstring injury. In a recent prospective study of elite Australian footballers, we observed five hamstring strain injuries as a consequence of kicking, four of which were located within the bicep femoris long head while one was to the semimembranosus.²

In the current, study both the biceps femoris and medial hamstring sEMG associated with maximal eccentric actions declined significantly more after kicking than in the control group. However, while the changes in biceps femoris sEMG were correlated with the changes in

eccentric knee flexor strength, the same was not true for medial hamstring sEMG. We have previously reported a similar correlation between reductions in biceps femoris sEMG and eccentric strength after sprint running,¹² and this unexplained finding warrants further investigation. Fine wire EMG suggests that the long head of biceps femoris exhibits progressively greater activation as the knee extends while the other hamstring muscles exhibit progressively less,²⁵ so perhaps, in the range of motion in which we have assessed sEMG (15-35° from full extension), the long head of biceps femoris has a greater role in torque generation than other hamstring muscles?

The number of kicks in Australian football matches averages 16.4 per player (2015 season), but this varies considerably depending on player position and ability. Nevertheless, the extent of kicking-induced fatigue observed in this study is likely far greater than that which is likely to occur in a competitive game. Nevertheless, the exhausting running demands of football matches sees players covering 12.2 ± 1.9 km, reaching maximum velocities of 30.1 ± 6.7 km h⁻¹ and performing numerous accelerations (246 ± 47 (>4 kmh⁻¹ in 1 s)) and decelerations, (14 ± 5 (over 10 km h⁻¹ in 1 s))²⁶ and this, combined with kicking, may have an additive effect on injury risk. Furthermore, training sessions involve significantly more kicks (~50-100+) than are performed in a game (unpublished observations). The amount of high-force kicking in training sessions may therefore influence the risk of hamstring injury in Australian Rules football.

We chose to assess the knee flexors at a much slower speed than the maximum angular velocities experienced in kicking. However, there are few commercially available isokinetic dynamometers that can assess torque at greater than 500°/s⁻¹. Furthermore, the chosen velocity of 180°/s⁻¹ has previously been used¹² to show decreases in eccentric knee flexor torque as a consequence of running induced fatigue.

Twitch interpolation is widely considered the most appropriate means of determining the completeness of voluntary muscle activation,²⁷ however, it is difficult to electrically stimulate the sciatic nerve and this makes it very challenging to obtain accurate assessments of hamstring activation. Surface electromyography has limitations when assessing muscle activation because it is influenced by factors other than motor unit recruitment and firing rates. For example, the sEMG signal is also influenced by the degree of motor unit synchrony, which is known to change with muscle fatigue. Nevertheless, the hamstring sEMG signals associated with maximal eccentric actions are smaller than those associated with concentric ones¹² and this matches the well-established pattern observed in other muscles assessed via twitch or 'train' interpolation.²⁸ Furthermore, muscular fatigue seems unlikely to account for a high proportion of the strength loss reported in this study because, in this circumstance, similar changes in eccentric and concentric strength would be expected. It therefore seems likely that the current sEMG findings are reflective of muscle activation and the changes in it induced by kicking.

4 1. Conclusion

This study showed that a reduction in eccentric knee flexor strength was accompanied with a decline in biceps femoris and medial hamstring sEMG activity following repeated drop punt kicking. These reductions may exacerbate hamstring strain injury risk independently or when coupled with high-speed running,¹² and prolonged match and training session exposure.¹¹

Therefore, the amount of kicking and running performed within a training session should be considered from the perspective of injury prevention.

5 Practical Implications

- Reductions in eccentric knee flexor strength and hamstring sEMG activity may exacerbate hamstring strain injury risk independently or when coupled with high-speed running, and prolonged match and training session exposure.
- Kicking volume and intensity within a single session should be considered from an injury prevention perspective.
- Impaired neuromuscular function of biceps femoris after kicking may provide further insight as to why this muscle has a greater susceptibility to injury.

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Figure 1 Pre to post mean changes in knee flexor torque. Ecc = eccentric contractions, Con = concentric contractions. Error bars represent SD.

Figure 2 Changes in mean normalized hamstring sEMG in peak eccentric and concentric isokinetic contractions for K and NK. K = kicking group, NK = no kicking group. Error bars represent SD.



